ALBERTA’S LITHIUM

Supply Chain Opportunities

Abstract

Summary of Challenges and Opportunities Identified in the November 8, 2019 Workshop

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Table of Contents

Introduction

The Alberta's Lithium Supply Chain Opportunity Workshop was held on November 8, 2019 at the University of Calgary, Alberta Canada[1].

The goal of the Workshop was to develop an understanding of the current status and maturity of Alberta's lithium industry (from raw material production to end-use), to identify potential commercial applications for Alberta and capture technical and economic challenges and gaps. The organizers brought together individuals from private industry, government and academia.

This report contains an abbreviated record of the Workshop and is intended to accurately capture knowledge shared during the workshop and ensure that the learnings and connections at the workshop can be shared with attendees and a broader network of interested parties.

The views expressed in this document represent the opinions and knowledge shared in the workshop and may not represent views held by the authors and workshop organizers.

Workshop Supporters and Organizers

- University of Calgary Innovation Portfolio, Office of the Vice-President (Research)
- Global Research Initiative (GRI) at the University of Calgary
- Canadian Lithium Association (CLA)
- Canadian Natural Resources Limited (CNRL)
- Alberta Ministry of Economic Development and Trade and Tourism (EDTT)
- June Warren Nickels (JWN)
- National Research Council of Canada (NRC)

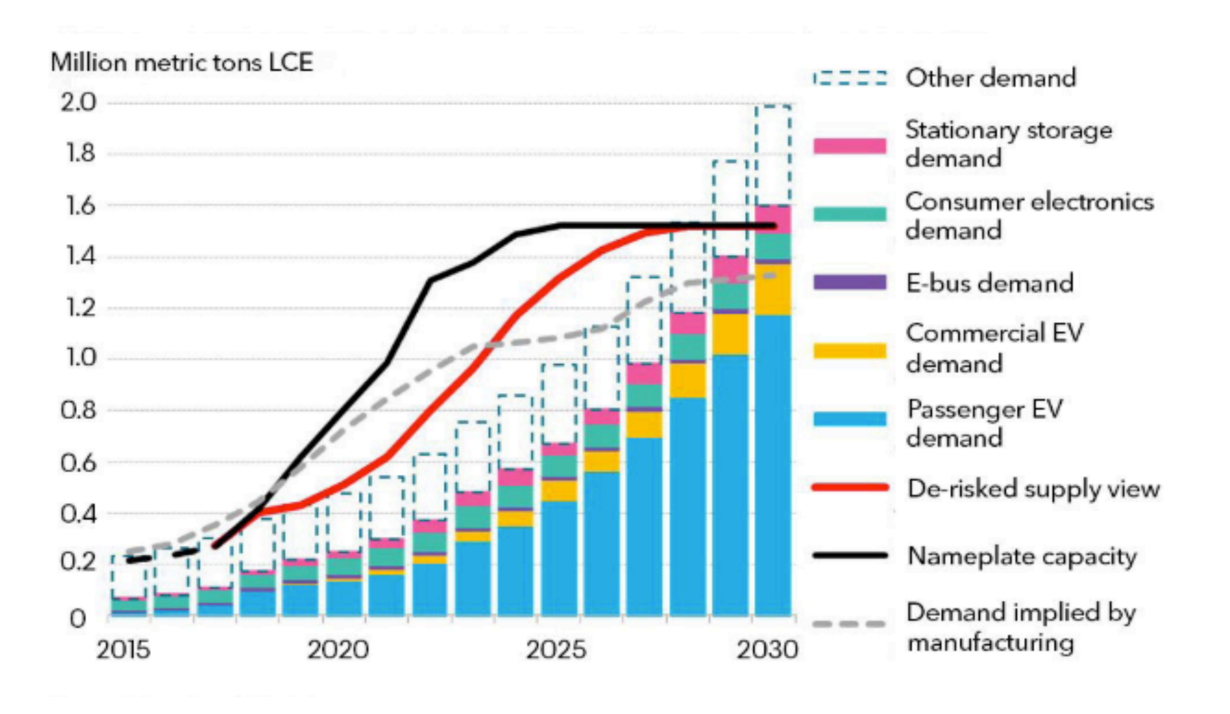
[1] See Appendix 1 for agenda of the event

Lithium 101

Historically lithium was primarily used as a specialty chemical in the form of soluble salts (lithium carbonate, lithium chloride or lithium sulphate) for a variety of non-battery industries including glassmaking, ceramics, pharmaceuticals, lubricants and battery applications for products such as electronic devices. Today, lithium demand is driven by the need for energy storage solutions, of which the fastest growing sector is the electric vehicle industry. With demand for battery materials increasing, commodity producers are being challenged to scale production while meeting strict quality standards. Lithium ion batteries require lithium carbonate or lithium hydroxide – demand for each product is dependent on the specific battery chemistry being currently produced.

Global Lithium demand is expected to increase from 300,000 tonnes lithium carbonate equivalent (LCE) in 2018 (including non-battery ”other” demand) to between 700,000 and 1 million tonnes LCE by 2025 (Figure 1), necessitating the development of new lithium resources. While supply and demand are roughly equal today, the exponential growth of the battery industry suggests demand may overtake supply towards the middle of the upcoming decade. Now is an important time to build and prepare to bring unconventional resources, like those found in Alberta, online.

Figure 1: Lithium supply & demand predictions by end use



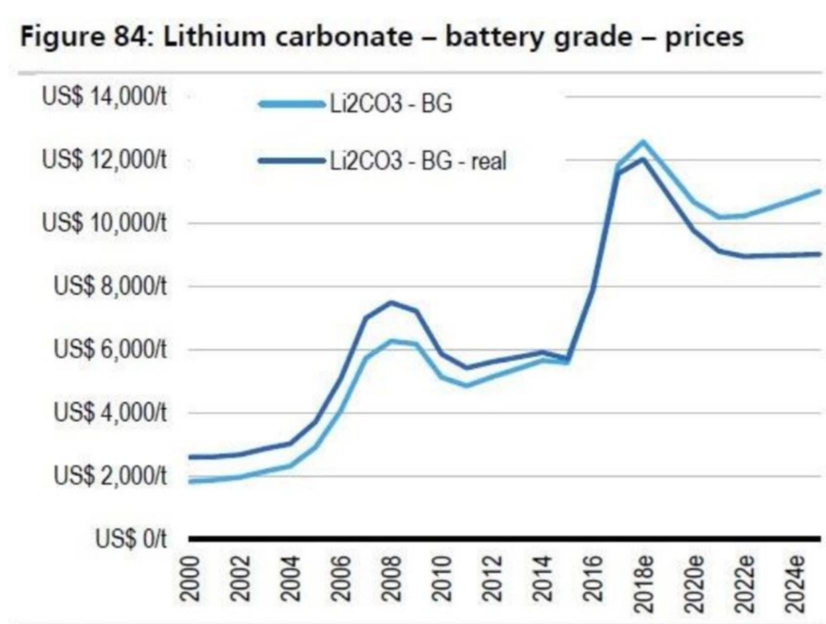
(Source: BloombergNEF, 2019)[i]

“The lithium industry has experienced dramatic price movements, rapid demand growth, a supply deficit for refined products and oversupply of mined products in recent years. Monthly average lithium carbonate spot prices fell from a peak of US$22.89/kg in February 2018 to US$11.28/kg by October that year, a fall of 51% largely because of supply side pressures. Prices have continued to fall into 2019, reaching US$9.56/kg in June, with prices expected to fall further in July.”[ii] (Figure 2)

Traditional sources of lithium include hard rock spodumene deposits and evaporative salars. Hard rock sources are mined primarily in Australia today and currently represent the biggest supply of lithium. There are some hard rock lithium mines in Canada and one in particular that is advancing towards production (eg. Nemaska in Quebec). These deposits are mined by blasting, crushing and grinding the rock into concentrated ore. This ore is further processed into battery grade materials. Some hard rock lithium deposits occur in pegmatite formations in northeast Alberta, but this lithium source is yet to be developed.

The second largest source of lithium today comes from South America’s evaporative salars[iii]. Lithium enriched brines are pumped to the surface and collected in vast evaporation ponds. The brine evapo-concentrates in the sun for 18-24 months before being processed into refined lithium products. Production of lithium by evapo-concentration has low overall recoveries.

Figure 2. Historic and Projected Lithium Carbonate (Battery Grade) Prices



(Source: Roskill, Benchmark Mineral Intelligence, USB estimates as cited by University of Michigan)[iv]

Lithium is the third smallest element and is highly soluble in water, such that it tends to remain as one of the last molecules in solution after other salts have precipitated out. This is observed in evaporating salt flats such as the Salar de Atacama in Chile and it has been theorized to occur in Alberta’s Devonian evaporites. More on the geology of Alberta’s lithium resources can be found in reports by the Alberta Geological Survey[v].

Another method of extracting lithium from brines is called Direct Lithium Extraction (DLE). This process, not yet commercialized, works by pumping lithium enriched brine to the surface, removing only the lithium, and reinjecting the brine back into the subsurface. DLE has a smaller environmental footprint and higher lithium recoveries when compared to current lithium production, making it an attractive potential alternative for brine developers. A number of DLE technologies are under development globally, including in Alberta (see Table 1). This is the proposed method to develop Alberta's unconventional lithium brine resources that occur in select reservoirs historically tapped for oil and gas production.

Alberta's Role in Canada's Emerging Lithium Industry

Lithium supply security has become a top priority for technology companies around the world. In 2018 the United States Department of the Interior published a list of 35 mineral commodities "considered critical to the economic and national security of the United States" [vi]. Lithium was one of the minerals on the list. Important private sector companies (e.g Tesla) have committed to sourcing lithium from North America. Canada is working with the United States to help diversify supply of these minerals and the first meeting of the U.S.-Canada Critical Minerals Working Group was held in October 2019[vii]. In parallel to this Natural Resources Canada has launched the Canadian Battery Initiative to "create a plan for how governments can enable the (battery) industry to thrive in the rapidly growing market for electrochemical energy storage technologies". Five recommendations have so far resulted:

1. Leverage Canada's Minerals and Metals to Foster a Domestic Industry
2. Attract a Leading Battery Manufacturer to Invest in Canada
3. Win a Fully Electric Vehicle Assembly Plant
4. Establish Canada as a Global Leader in Stationary Energy Storage
5. Own Specialty Markets and Battery Technologies of the Future, including Recycling

The Federal Government is seeking input from Western Canadian organizations on the plan.

Alberta has the potential to significantly contribute to the growth of this new industry as it has already experienced investment by private corporations. These corporations are establishing a presence along the whole battery value-chain – from production of lithium to the assembly and sale of battery packs and modules. Even though the industry is experiencing barriers to development, Alberta's entrepreneurial spirit, combined with its technical and business expertise, creates a significant opportunity for the province to pursue.

Upstream: Current Reality of the Nascent Western Canadian Lithium Brine Industry

Barriers to Development

The most significant hurdles are currently:

1. Regulatory uncertainty in the absence of defined legislation; overcoming this regulatory uncertainty will be prerequisite to developing the necessary pilot to prove out the technology;
2. Promoting awareness and educating stakeholders about this nascent industry;
3. Access to risk capital willing to invest in the first generation of Li extraction facilities based on novel technologies and Li-dilute brines, and
4. New technology that is not yet commercialized;
5. Lack of government incentives / financial tools to attract invest in the development of these resources while industry works to validate economics.

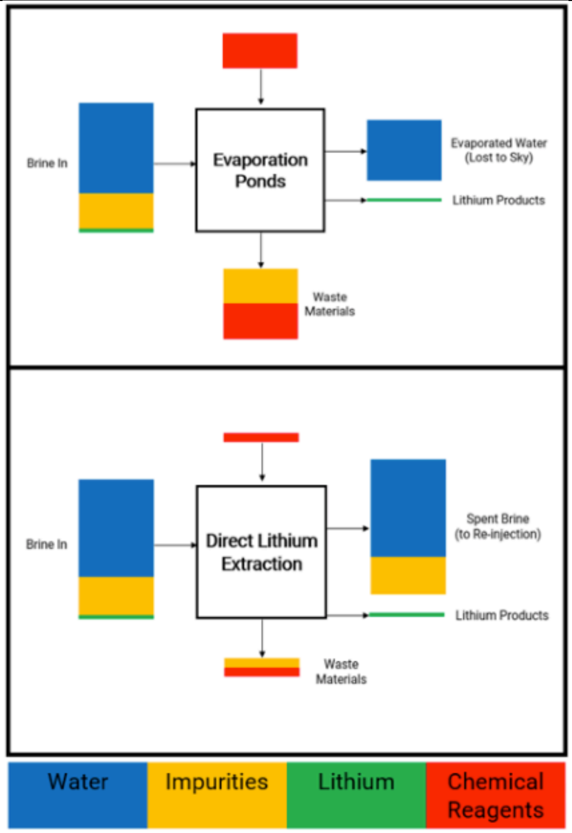
New Technology Under Development

Alberta contains a significant lithium resource within high-salinity brines with up to 140 mg/L[viii] lithium, though reported industry averages are around 75 mg/L lithium[ix]. These brines contain much higher amounts of sodium, magnesium and calcium relative to lithium, as the solubility and size of lithium in the presence of abundant impurities can make it difficult to isolate and process. This is especially true with traditional methods such as evaporative salars which are not suitable for Alberta's climate.

Presently there is considerable work being done to develop direct extraction technologies to selectively remove lithium from brines, using mechanisms such as membranes, adsorption, ion exchange, electrodialysis, solvent extraction, and others. These technologies are in various states of commercial readiness, ranging from lab scale to field pilot scale. The direct lithium extraction (DLE) model involves producing brine to the surface, removing lithium, and reinjecting the brine into the subsurface (Figure 3). This is expected to reduce waste and land disturbance, improve lithium recovery and increase efficiency when compared to salar mining.

Several of the technologies (Table 1) developed in Alberta have seen financial support from funding agencies like Alberta Innovates and the Industrial Research Assistance Program. There was also a recent investment by major global lithium company Livent Corporation with E3 Metals Corp to help de-risk and support development of their direct lithium extraction process[x].

Figure 3: Direct Lithium Extraction vs. Evaporation Ponds



(source: Jade Cove Partners, 2019)

Table 1: Summary of Technology Development in Alberta

COMPANY NAME	TECHNOLOGY TYPE	TECHNOLOGY STAGE	PARTNERSHIPS
Purlucid	Molecular Sieve/Ion Exchange	Expanding commercial unit in operation	MGX, Eureka
E3 Metals Corp	Ion Exchange	Lab scale flow system, pilot development underway	Livent Corporation, GreenCentre Canada, U of A
LiEP Energy Ltd	Electrochemical	Lab scale prototype, early stages of designing field/pilot demonstration	TBD
Summit Nanotech	Membranes and Nanoparticles	Lab Scale	NRCan, TransAlta
Prism Diversified	Undisclosed		

Source: Company Information

Brine Production

Because Alberta's lithium resource is relatively low concentration compared to global sources, large volumes of water production and reinjection (over 100,000 m3/d for a 20,000 tonne LCE/year project) are required to scale lithium production in the province. Reinjection of brine back into the same reservoir, some distance from where the brine was originally extracted, is anticipated. A helpful analogy for this is an enhanced oil recovery scheme, where injection into the reservoir enhances recovery from through pressure support. Over many years, depending on the design of the production and injection well network, lithium void brine would arrive at the production wells. These wells would be shut in after an economic lithium concentration limit is reached. Another production area would then likely be developed nearby, leveraging much of the same infrastructure to flush another portion of the reservoir. The Leduc is 100's of km^2 in area, ideal for implementing this type of recovery.

There is concern among some that the production of large brine volumes are logistically challenging and cost-prohibitive. The potential for brine production volumes in Alberta are not well represented in the historical database because the goal in oil and gas is to produce as little brine as possible. However, the Leduc reservoir in particular is uniquely capable of producing large volumes of brine due to its thickness, areal extent and reservoir properties.

Currently, the oil and gas industry produces significant volumes of brine as a byproduct so the handling of brine in smaller volumes is well understood in Alberta. Many mature hydrocarbon pools produce over 95% brine today with less than 5% hydrocarbon production.

Globally, companies like Lanxess and Albemarle have been producing Bromine from Smackover brines in the US for decades in similar volumes that would be required in Alberta. Lanxess has several Bromine plants processing over 50,0000 m^3/d in Arkansas where a lithium project is currently being piloted. Similar large volumes are also currently being pumped daily through existing water flood facilities in Weyburn, Saskatchewan.

Resources and Reserves

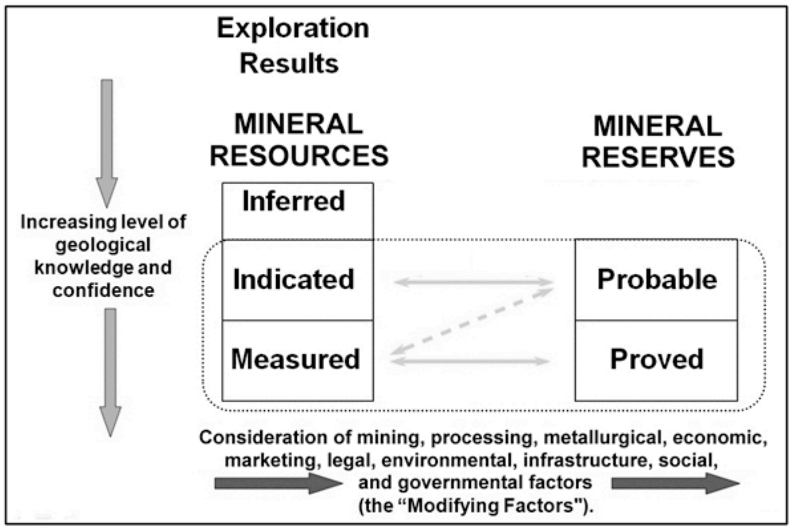
There is clear guidance by the Canadian Institute of Mining (CIM) for how to define lithium brine resources and reserves that is applied globally in Canadian, American and South American projects. Next-generation extraction processes are expected to inform and evolve the guidance for how to calculate and report lithium resources. By some industry estimates Alberta's lithium resource is comparable to some of the world's top lithium exporting nations[xi].

Publicly disclosed company resource estimations are completed by independent 3rd parties, for example Matrix Solutions, Fluid Domains or APEX Geoscience. Estimations much be overseen by a Qualified Person (QP), under the guidance of a Canadian National Instrument for mineral resource classification code (NI 43-101). This guidance ensures that resource estimations are conducted ethically by ensuring independence from resource companies.

Generally, a resource is classified in three categories based on confidence in the resource. In order of confidence, this is Inferred, Indicated and Measured. In cases where historic data is not available, the process to upgrade to Indicated and Measured involves drilling new holes to acquire additional data. The process in the Leduc Reservoir is much simpler due to the large amounts of historic data and seismic available.

To convert the resource to a mineral Reserve, a report is required (Pre-Feasibility Study or PFS) that includes a lithium process flow sheet in detail, infrastructure plan along with supporting project economics. When reporting a Reserve, Indicated resources convert directly to Probable and Measured resources convert directly to Proven (Figure 4).

Figure 4: Summary of Mineral Resources and Reserves



(Source: Canadian Institute of Mining)

Repurposing Oilfield Infrastructure

Existing oil and gas infrastructure and data is relied upon heavily for sampling and mapping Alberta's lithium resource. There are thousands of wells that have intersected Alberta's lithium prospective reservoirs. Those that are currently active provide opportunities for sampling with operator permission. Those that are inactive provide opportunities to conduct sampling deeper in the reservoir or away from oil and gas production.

A select few wells drilled through the correct zones may be recompleted for testing production but that has yet to be done due to the inherent complexities with liability transfer. New technical and contractual innovations, such as a regulatory scheme that addresses liability concerns among infrastructure owners and potential lithium developers could remove barriers around infrastructure access for expanded testing programs.

In a commercial scenario, it is possible to drill from existing abandoned well pads and connect to existing pipes, taking advantage of brownfield operations and significantly reducing net-new land disturbance in comparison to global brine production methods (Figure 4). Alberta's expected land disturbance on a per-tonne basis is estimated at only 3%[xii] of evaporation pond operations and would be similar to those of a conventional oil field with small surface leases to drill wells. Some repurposed wells or newly drilled wells could also be utilized to produce geothermal energy depending on their depth and local temperature gradient. It may also be possible to simultaneously produce other co-products as described in the next section.

Figure 4: Direct Lithium Extraction Footprint

(Source: Salar de Atacama, Chilie, SQM)

Value Streams in Addition to Lithium

Other alternative product streams were also discussed such as other rare, heavy or otherwise desirable elements such as strontium sulphate. However, current water compositions suggest that lithium is still the single most valuable component at the given concentration of each in Alberta brines presently. Some other valuable streams may also derive from processing the brine water potentially for agricultural use or fracking. Currently, water rights associated with produced brines are owned by the government.

Co-products that could support economics include:

- Geothermal heat
- Agricultural water
- Potable water
- Petroleum/natural gas
- Strontium sulphate
- Bromine
- Thorium
- Zinc

Similar to lithium development, the production of other value-added products could be a challenge as there is regulatory uncertainty in the absence of defined legislation.

Regulatory Framework

Current policy and legislation for lithium development in Alberta is captured mostly within the Metallic and Industrial Minerals Act. Tenure and Royalty legislation has been developed specifically for more traditional mining methods and certain aspects of this legislation hinder the lithium industry inadvertently.

Tenure: Lithium development in Alberta requires technology development, in addition to a blend of both oil and gas and mining techniques, both of which are not adequately contemplated in the current policy. To compete globally, lithium development requires large metallic and industrial minerals permits due to the large-size, yet low grade, nature of the resource. These large permits must be held and protected while technology is developed to remain competitive.

Small changes in policy can likely reduce the burden on this nascent industry as it becomes properly established. Examples of this would be to expand the first mineral assessment term from 2 years to 4 years to allow adequate time for the industry to develop and evolve to large exploration amounts (eg. Inactive well completions and testing). “Non-traditional” expenses, such as technology development, should also to be included in expenditure amounts; currently this is allowed on a case-by-case basis.

Permitting and Approvals: Alberta’s emerging lithium industry could fall under Alberta Energy Regulator, though this determination has not been finalized by Alberta Energy. Lithium development is very similar to oil and gas development, requiring the use of fluid processing equipment, pipelines and wells. For this reason, existing Alberta Energy Regulator Directives could likely apply, reducing the need for completely new policies.

Royalties: Regulators may adapt the existing system for metals or salts. Lithium could be considered either but financial impacts would vary significantly.

Midstream: Challenges and Opportunities in Investing in Alberta's Value-Added Battery Industry

Alberta’s Value-Added Opportunity

Alberta’s value-added battery industry has all of the key competencies necessary to produce intermediate and assembled battery products exist in Western Canada. Some examples of companies working on batteries in Alberta participated in the workshop. Excell Battery Company and Canadian Energy Corp are battery manufacturers currently operating in Calgary and across Canada, producing custom batteries for oil and gas (e.g. downhole equipment), grid storage and medical applications. NanoOne is a cathode manufacturer from B.C. originally working on lead acid batteries and hydrogen fuel cells before transitioning to Li-battery electrodes including LFP (lithium iron phosphate), LMO (lithium ion manganese oxide) and NMC (lithium nickel manganese cobalt oxide). Applied Quantum Materials Inc. (AQM), a nanomaterial company, has developed the first industrial scale process for producing silicon nanoparticles, necessary for high-cycle capacity silicon anodes.

The next ten years is predicted to show an exponential growth in the production of batteries and their components, many of which can be produced competitively in Canada. It was suggested that this may be supported in part by Tesla’s commitment to source their materials from North America. Barriers to growth include a lack of knowledgeable finance in their sector, the currently small scale of domestic battery and EV production as well as the prevalence of oil & gas mindsets.

Now is the time to be designing new processing facilities able to selectively extract lithium from brines directly. This will allow additional refining into value-added products further along the value chain such as electrolytes, electrode sheets, cells or fully assumed modules. Much of this supply chain is already developed within Alberta and in Canada. Capturing strategic niches for building upstream battery component industry may not be as difficult as one would assume. Because each battery end-use application has highly specialized demands, each order tends to be highly customized in terms of purity and other specifications. It may therefore be more useful to consider battery chemicals as lower volume specialty chemicals rather than high volume commodity chemicals which are identical for each buyer.

Transitioning Academia into Industry

Industry relations with particular researchers and labs, along with the ability to hire specialist graduate students following project completion can accelerate academic work into practical industry developments. This could be supported by government funding and fund stacking to support projects, in addition to test facilities. There is a prototype pouch cell production line operated by NRC available for collaboration in Montreal as part of the Canadian Battery Initiative. Also, it is possible to contact the NRC Clean Growth Hub to talk with an associate who knows the ecosystem and can help connect companies to the most applicable services.

Vertical Integration & Recycling

Alberta companies could vertically integrate beyond lithium salt products into battery components, however the extent of this opportunity is not well captured. An example of this would be manufacturing a finished battery component such as an electrode sheet roll instead of lithium carbonate or lithium hydroxide. There is a lot of established expertise in Alberta and Canada throughout the value chain and strategic partnerships can be particularly valuable in this formative period. There are opportunities for specialty mid-stream producers to make battery components specific to particular extreme environmental conditions or performance requirements particular to our local market or smaller application niches.

Battery material recovery in recycling is important to consider, as the form of recovery determines whether material can be reused as a battery component or must be downcycled. Developing enterprises for repurposing batteries and battery components at the end of their useful life was one strategic niche identified by the Canadian Battery Initiative as an opportunity for Canada. Currently there are very few options for end-users to deal with batteries at the end of their life. Ultimately recycling could become the dominant material input for new batteries, although today the technology is not well established.

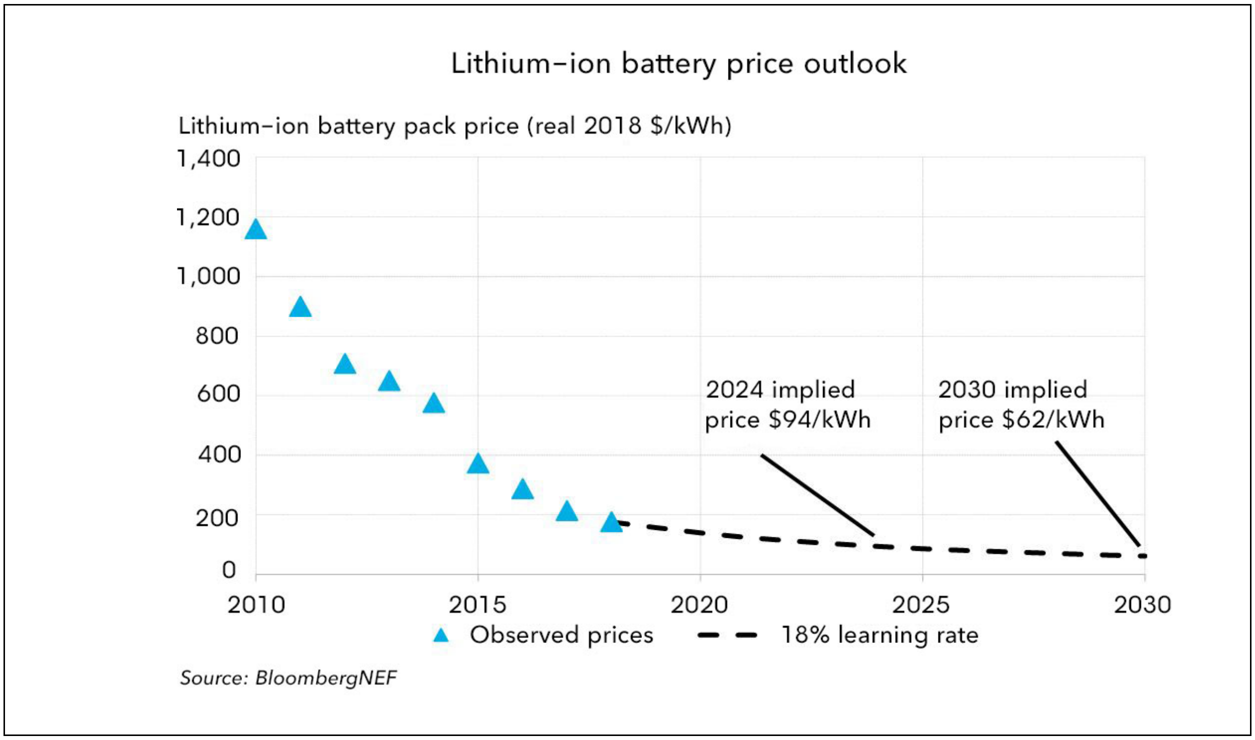
Downstream: The Case for Using Lithium Batteries in Alberta

Grids and Vehicles: The Role of Batteries

The world is transitioning from a linear, single-source grid to a grid network of distributed energy sources, storage points and consumers. Residential, commercial and utility scale batteries as well as EVs potentially will become the dominant form of energy storage on the grid with Li-ion battery prices currently around

$200/kWh dropping to $94/kWh by 2024 and $62/kWh by 2030 (see Figure 5). Riding the same cost curve as EVs, the energy storage market will reach $100 billion per year by 2025[xiii].

Figure 5: Lithium-ion Battery Price Outlook



(Source: Bloomberg New Energy Finance[xiv])

This evolution will require more advanced grid balancing to apply thresholds at peak production hours to store excess energy for periods of high demand, important for variable renewable energy sources. A significant renovation of our physical electrical infrastructure, especially the introduction of ubiquitous EV charging stations, are anticipated. These charging stations may be connected to the grid bidirectionally, using the vehicle as an active storage device while parked. Other strategies can be employed such as clustering of EV charging in certain areas and encouraging people to charge at certain times can be used to promote better grid balancing. However, a more coherent and holistic plan for our grid will have to be developed for large scale implementation, even just for subset problems such as the electrification of bus fleets.

Battery Storage Architecture

Battery cells are the fundamental unit which determines performance and cycle life in energy storage. When many cells are combined, they form a pack and these packs are assembled into larger modules which are together managed by power control and energy management systems to avoid accelerated charging and other issues affecting battery performance. These modules are also connected to the cloud where the data can be used for grid management.

Safety and thermal management are of paramount importance. Depending on the discharge rate and where the battery is in its cycle life, there is the propensity for heat accumulation. This can be mitigated through the use of battery management control systems as well as more conventional heat exchangers and appropriate thermal materials for passive heat management.

Recycling

As the industry grows, depleted batteries will begin to stockpile if recycling does not scale. Lithium battery recycling can be dangerous due to the current use of hydrocarbon electrolytes and their high energy density. The industry is still nascent, and there are technologies in BC and Ontario to recycle batteries. Europe is leading an industrial consortium to create a battery recycling fund. Battery producers have designed their battery systems to be modular and easily broken into constituent cells, therefore most of the effort must be applied towards breaking down and processing degraded cells.

Reflections of a Battery Expert

Research and Development into next-generation Li-battery chemistries and materials is necessary to increase safety, cell energy density, charge/discharge rate, cycle stability, and operating voltage – all while balancing costs. The task is to find the best combination of two mutually compatible anodic and cathodic materials each with respective redox reactions (a type of chemical reaction) that satisfy the above criteria. In particular, research is ongoing in the utilization of inexpensive Alberta sulphur and silicon to produce Li-battery electrodes with higher energy density and fewer critical elements such as cobalt.

Pure metallic lithium is the ideal battery cathode material, but it is highly reactive and unstable, combusting in contact with air and/or water. This propensity supports the fact that lithium-air batteries, if feasible, would have one of the highest energy densities and operating voltages out of any possible lithium battery.

Solid state batteries represent an important area of development whereby liquid electrolytes which are often combustible organic compounds are replaced by non-flammable, conductive solid materials through which lithium ions can easily diffuse. A solid electrolyte has been developed in the form of a lithiated-garnet ceramic made using Rare Earth Elements (REEs) such as lanthanum, tantalum and niobium. After overcoming the challenge of creating a continuous and stable bonding surface between the garnet and metallic lithium the University of Calgary was able to demonstrate the ability to operate a Li-metal battery in contact with an aqueous electrolyte, with the garnet as an intermediator. The electrode-electrolyte composite was even stable against degradation during short circuiting, after which the battery performance returned almost to the same level as before the short. Research is ongoing to apply these innovations towards a robust, scalable Li-metal/Air battery.

It could prove strategic for Alberta to further invest in research and development activities related these emerging areas of technology development.

Life-Cycle Considerations for Li-Batteries

Establishing a clear and transparent story around the environmental impact of the lithium industry will be important in order to establish markets for Alberta's resource. The Canada Battery Initiative identified

Canada's 'green brand' as a potential competitive advantage as global customers increasingly demand sustainable batteries. Comprehensive and well documented life-cycle assessments (LCA) are a key piece of evidence major customers will be looking for.

The full lithium ion battery life cycle can roughly be broken into four main components:

1. Extraction method and source of the lithium;
2. The intermediate battery component it becomes in the value chain;
3. The final product; and
4. How that assembled battery is subsequently recycled

The LCA of a lithium ion battery depends heavily on how and where raw materials and the final product is produced. Solid rock resources tend to have higher environmental impacts compared to processed brines. Energy consumption, greenhouse gases, and other pollutants vary depending on the form of the lithium salt content, lithium hydroxide being more difficult to produce than its carbonate, as well as the intermediate components such as various cathode materials. For each of these there are concerns around ecotoxicity, eutrophication, smog, particulates, cancer and other human health impacts. Aspects of end-use product impact assessment considers what the battery is replacing, such as a combustion engine, as well as the energy source which charged the battery.

In Alberta, upstream lithium production will primarily be a story of brine management. Lithium will be selectively extracted from the brine which will be reinjected into the formation. Proposed risks around this include the potential for seismicity or contamination of other water bodies; industry considers this risk to be low.

More detailed sampling and composition data will help define contaminants and valuable elements in brines around the province. There is the possibility for co-producing additional products from these brine streams which will have their own unique life cycle impacts. Re-utilization of brownfield developments will be important for minimizing additional land-use impact while also taking advantage of existing infrastructure.

Conclusions

Alberta's Lithium Value Proposition and Competitive Advantages

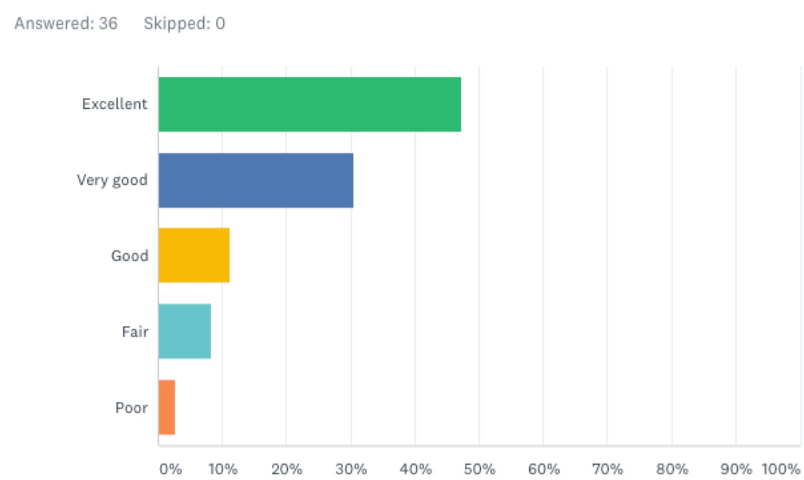
1. Size of Resource – Alberta is anticipated to host one of the largest sources of lithium globally[xv].
2. Existing Data & Infrastructure – Alberta's lithium is hosted within some of Alberta's most economically important reservoirs and is located in the heart of the oil patch. There are thousands of wells with associated data that have been drilled and the area is blanketed in a network of roads, powerlines and oilfield equipment that can be repurposed for lithium development.
3. Skilled Workforce – Developing lithium requires a similar skill set to oil and gas, requiring drillers, engineers, geologists, project managers, construction, accounting and more. Alberta has this expertise in abundance.
4. Responsible Resource Development – The land disturbance required for Alberta lithium will be a small fraction compared to other traditional global sources (hard rock and salars). Emissions from electricity can be reduced through a renewable energy mix and CO_2 sequestration. In addition, the development of a lithium-ion battery industry is expected to eliminate tailpipe emissions from the transportation industry while also enabling the electrical grid to more renewable electricity generation via grid-scale energy storage.
5. Supply Chain Development – Value added manufacturing and end-use applications are already underway in Alberta. Becoming a raw material provider could strengthen Alberta's position to attract additional Li ion battery-related industry and associated economic development to the province. This is aligned with the Canadian Battery Initiatives recommendations:
    - Leverage Canada's Minerals and Metals to Foster a Domestic Industry
    - Attract a Leading Battery Manufacturer to Invest in Canada
    - Win a Fully Electric Vehicle Assembly Plant
    - Establish Canada as a Global Leader in Stationary Energy Storage
    - Own Specialty Markets and Battery Technologies of the Future, including Recycling
6. Jurisdiction – Alberta is a stable, industry friendly province looking to diversify its economy.

Opportunities & Recommended Action Items

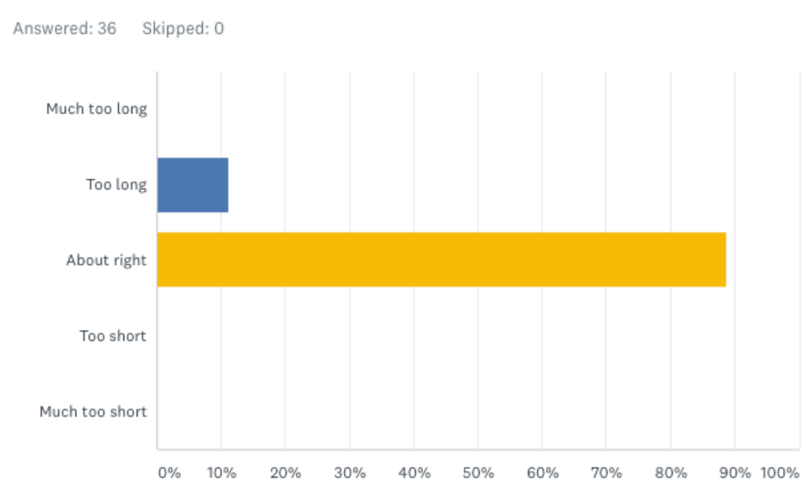
Opportunity	Recommended Actions
Build capacity within the Canadian Lithium Association to advocate, educate and present a united industry voice	• CLA to explore partnerships and funding opportunities • Targeted membership drive • Solicit volunteers
Amplify Alberta's lithium opportunity through engagement with the Canadian Battery Initiative	• Event participants & stakeholders are invited to provide feedback and opinions on a set of ideas; these will be presented to the CBI by the CLA in early 2020
Enable lithium industry development through regulatory certainty	• Alberta Energy to provide a determination on the regulator for lithium projects • Advance a lithium development framework that leverages existing regulations • Innovate solutions to liability transfer challenges to enable lithium exploration (sampling, testing)
Petrochemical Diversification Program	• Determine if this is an opportunity for a battery chemistry production facility investment?
Focus on Niche Applications for Alberta's Supply Chain	• Study potential niche applications or markets Alberta could carve out a competitive advantage? Batteries for drones? Medical devices? Others?
Build Confidence in Alberta's Lithium Supply Chain Opportunity	• Independent review/estimation of Alberta's lithium resource size • Independent assessment of lithium extraction economics in Alberta • CLA to provide open-source data and information about Alberta's lithium opportunity
Support and Enable the Development of Li-Extraction Technology for Alberta Brines through Financial Tools and Incentives	• Scientific Research and Experimental Development incentives are necessary to progress the industry as a whole • Investor tax tools can enable industry to attract risk capital • CLA can provide information to advise financial incentives that will enable the industry as a whole (upstream to downstream) • Broaden grant funding opportunities to include full LCA life cycle greenhouse gas (GHG) abatement benefits

Appendix 1- What we Heard - Survey Results

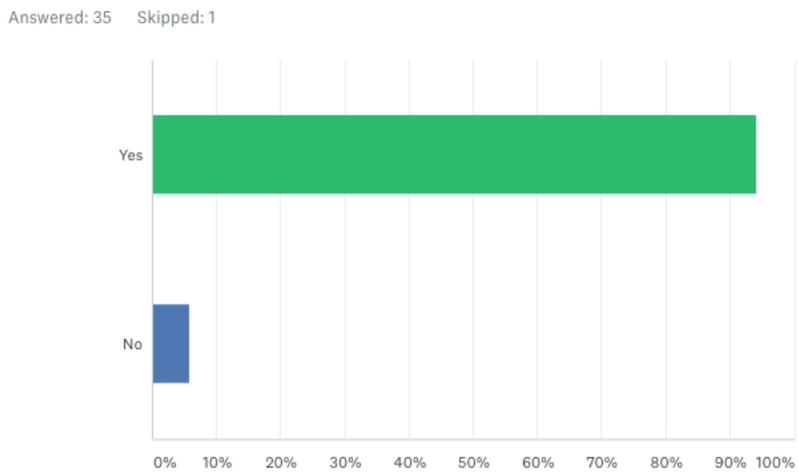
Question 1: Overall, how would you rate the event?



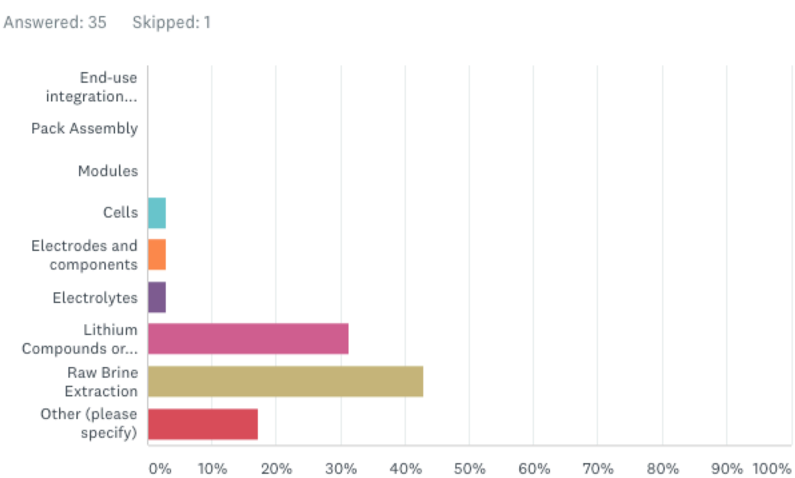
Question 2: Was the event length too long, too short, or about right?



Question 3: Based on what you heard and what you know, do you believe there is an opportunity related to lithium that Alberta should pursue?



Question 4: If you had to choose one "rung on the ladder" for Alberta to focus on which one would it be?



Question 5: Why did you choose what you chose in Question 4?

Response Summary:

RAW BRINE EXTRACTION	LITHIUM COMPOUNDS	ELECTROLYTES	CELLS
• Resource development is Alberta's Expertise • Brine extraction is the most immediate opportunity • Focus on reducing brine production costs • Large resource • Existing infrastructure • Industry momentum	• Versatile product • Quickest path to market	• Solid state is the future; Alberta should focus effort here	• This is a growing industry that Alberta should participate in

Question 6: In your opinion what are the top two obstacles that are preventing a lithium opportunity from being realized?

Summarized trends in order of highest occurrence:

1. Capital Investment (17)
2. Extraction technology not yet commercial in for lower-grade resources (13)
3. Lack of regulatory framework for lithium (10)
4. Costs, economics & lithium prices (10)
5. Lack of planning, long-term vision & strategic clarity (5)
6. Lack of political support & government collaboration (3)
7. Location not proximal to manufacturing in eastern Canada or needs access to tidewater (2)

Question 7: What is one recommendation you would make to help advance this sector?

Summarized trends in order of highest occurrence:

1. More workshops/conferences (5)
2. Attract Investment, public & private (5)
3. Regulatory clarity, certainty and ease (4)
4. Clarity on economic feasibility (4)
5. Open source data & learnings (4)
6. Advocacy to build awareness (2)
7. Government engagement (2)
8. Research & Development (2)
9. Join provincial and national efforts (2)
10. Partnerships (2)

Appendix 2 – Workshop Agenda

Agenda- Alberta's Lithium Supply Chain Opportunity. November 8, 2019- Calgary					
8:30	8:40	Welcome	Ian Gates	Director Global Research Initiative	University of Calgary
8:40	8:45	Inspiration for event	Jeff Bell	Sector Lead Emerging Technologies	Alberta Government
8:45	8:55	Inspiration for event	Liz Lappin	Director	The Canadian Lithium Association
8:55	9:05	**Lithium related research and development in the Alberta context**	Dave Van Den Assem	Senior Manager	Alberta Innovates
9:05	9:50	**Lithium 101**	Lori Walton	President	CDL Ventures North
9:50	10:05	Coffee Break			
10:05	10:25	**Alberta's role in Canada's emerging lithium industry**	Adam Tuck	Program Leader Energy Storage	National Research Council
10:25	11:45	**Upstream- "Current reality of the nascent Western Canadian lithium brine industry"**	Chris Doornbos	CEO	E3 Metals
			Haafiz Hasham	President	LiEP Energy
		Moderator:	Alex Grant	CEO	Jade Cove Partners
		Dr. Cathryn Ryan, Associate Dean, Research and Graduate Education, University of Calgary	Steve Shikaze	Senior Hydrogeological Engineer	Matrix Solutions, Inc.
			Eric Pelletier	Director	The Canadian Lithium Association
11:00	12:30	Lunch			
12:30	12:50	**Reflections of a battery expert**	Dr. Venkataraman Thangadurai	Associate Head Physical Chemistry	University of Calgary
12:50	2:10	**Midstream - "Challenges and opportunities in investing in Alberta's value-added battery industry"**	Dr. Ania Sergeenko	Postdoctoral Fellow	Applied Quantum Materials
		Moderator:	Brendon Sauer	Product Manager	Canadian Energy
		Dr. Michael Fleischauer, Associate Research Officer, National Research Council	Stephen Campbell	CTO	NanoOne
			Ian Kane	President	Excell Battery Company
2:10	2:25	Coffee Break			
2:05	2:25	**Life-cycle considerations for lithium batteries**	Dr Joule Bergerson & Emily Nishikawa	Canada Research Chair in Energy Technology Assessment	University of Calgary
2:25	3:45	**Downstream - "the case for using lithium batteries in Alberta"**	Brent Harris	Founder & Executive VP	Eguana
		Moderator:	John Rilett	Director Energy Solutions	Enmax
		Megan Lohmann, Head of Community Energy Management, Community Energy Association	Connie Stacey	CEO	Growing Greener
3:45	3:55	Closing Remarks	Liz Lappin	Director	The Canadian Lithium Association
3:55	5:00	Networking Coffee			

Appendix 3 – End Notes

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[iii] https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/mcs-2019-lithi.pdf

[iv] https://energy.umich.edu/news-events/energy-economics-weekly-briefings/story/raw-materials-used-to-make-lithium-ion-batteries/

[v] https://search.aer.ca/ags-en/search/theme/ags?fq%5B%5D=feed%3Aall&q=lithium

[vi] https://www.usgs.gov/news/interior-releases-2018-s-final-list-35-minerals-deemed-critical-us-national-security-and

[vii] https://ca.usembassy.gov/first-meeting-of-the-u-s-canada-critical-minerals-working-group/

[viii] https://ags.aer.ca/activities/lithium

[ix] https://www.e3metalscorp.com/documents/#technical-reports

[x] https://www.mining.com/e3-metals-livent-team-up-on-lithium-development-project-in-alberta/

[xi] https://www.e3metalscorp.com/documents/#technical-reports

[xii] E3 Metals Corp, personal communication

[xiii] https://www.greencarcongress.com/2017/07/20170731-lux.html

[xiv] https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

[xv] https://www.e3metalscorp.com/documents/#technical-reports